Use of Sub-Slab Sampling to Identify Source of VOCs in Indoor Air in Homes Near the Former Raymark Site

U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Ground Water and Ecosystem Restoration Division
Ada, Oklahoma

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(Vapor Intrusion Conference Call)

Primary Investigators in Raymark Study

- Dom DiGiulio U.S. EPA, ORD, NRMRL, Ada (principal investigator), OK
- Cindy Paul, U.S. EPA, ORD, NRMRL, Ada, OK
- Ron Mosley, U.S. EPA, ORD, NRMRL, RTP,NC
- Ray Cody, U.S. EPA New England Regional Office, Boston, MA
- Scott Clifford, U.S. EPA New England Regional Lab, North Chelmsford, MA
- Peter Kahn, U.S. EPA New England Regional Lab, North Chelmsford, MA
- Annette Lee, XDD Ltd.
- Kaneen Christensen, formerly of XDD Ltd.

Primary Elements of Study

- Ground-water and soil-gas sampling for VOCs
- Outdoor, indoor, and sub-slab sampling for VOCs (15 homes, 1 business)
- Air exchange rate testing and indoor air and sub-slab sampling for radon

Primary Objectives:

- Develop a protocol for sub-slab vapor probe installation (complete)
- Assess potential bias associated with sub-slab sampling (complete)
- Develop an algorithm to utilize indoor air, outdoor air, sub-slab gas, and soil-gas and/or ground-water data to assess sources of indoor air contamination (ongoing)

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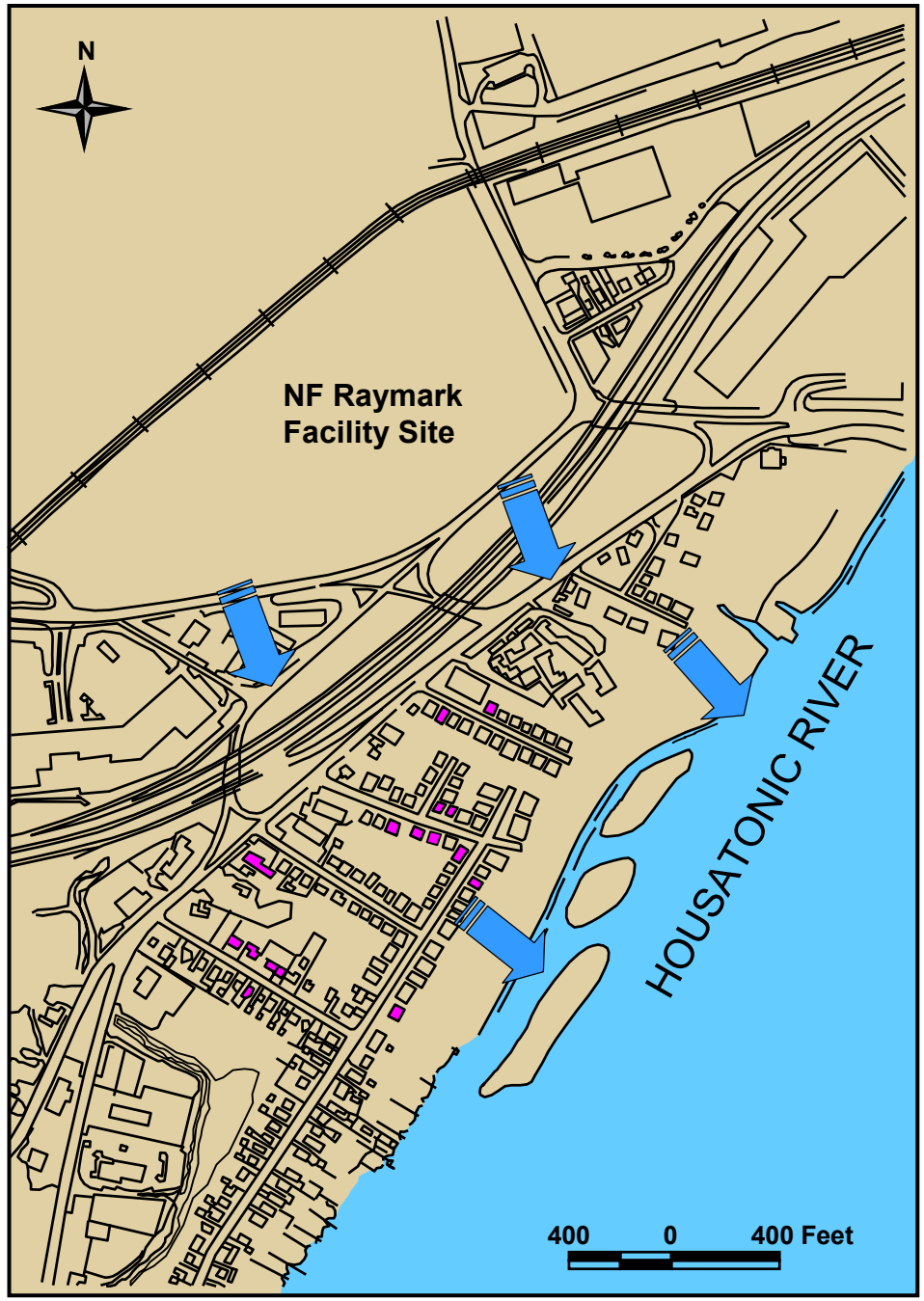
Case Study: Homes near the Raymark Superfund Site



Generalized Groundwater Flow Direction

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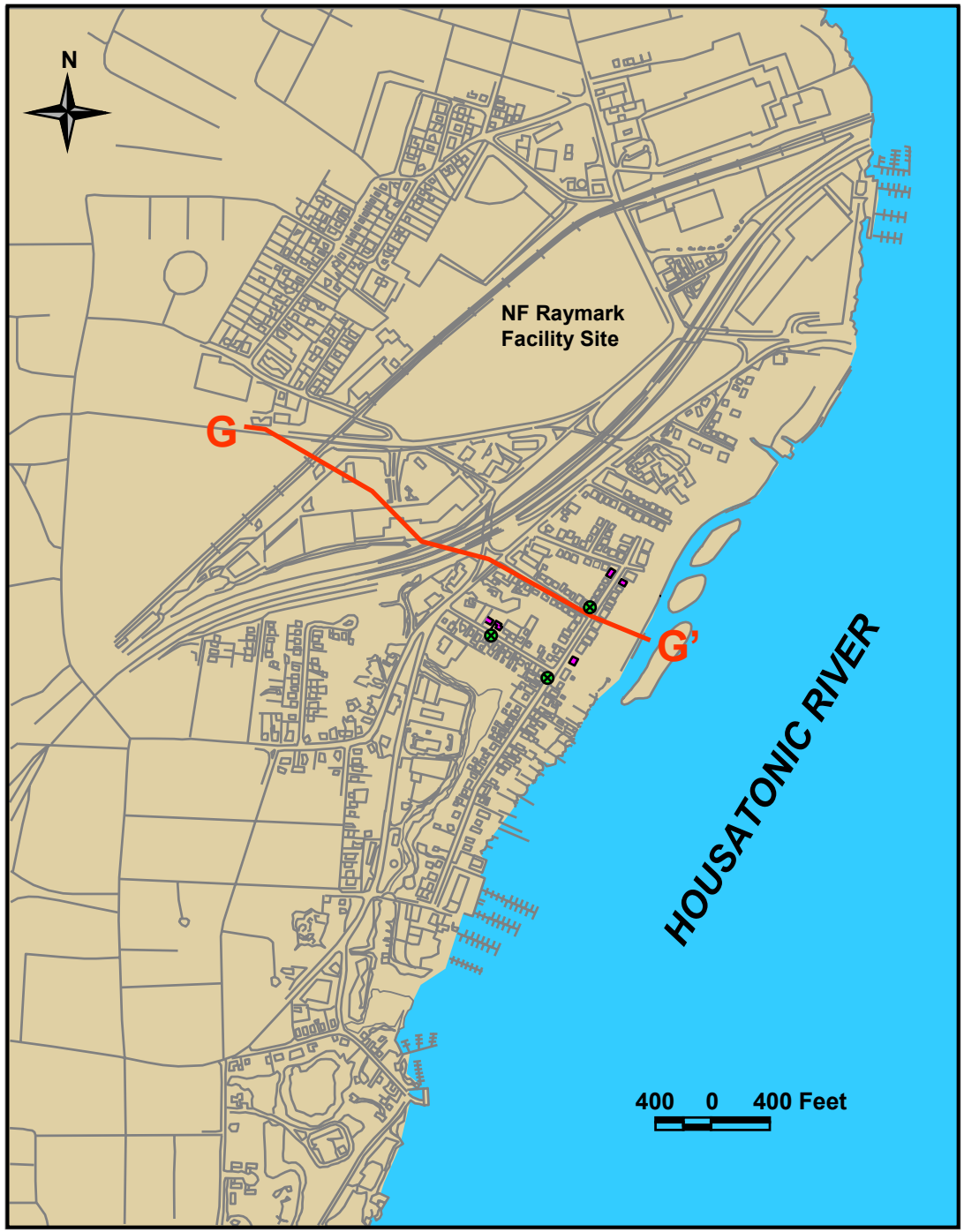
Geologic Cross-Section



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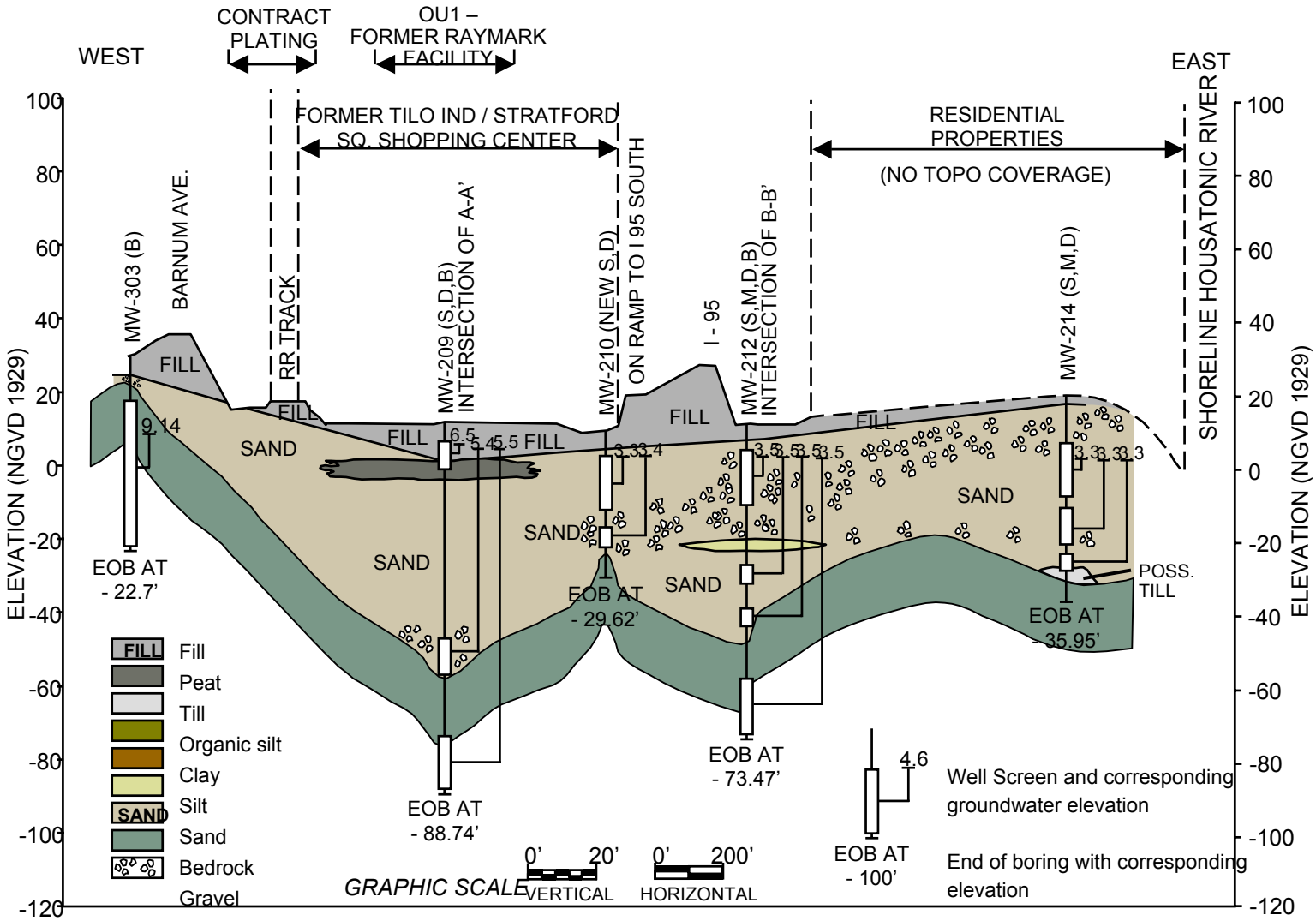
Cross-Section G-G”



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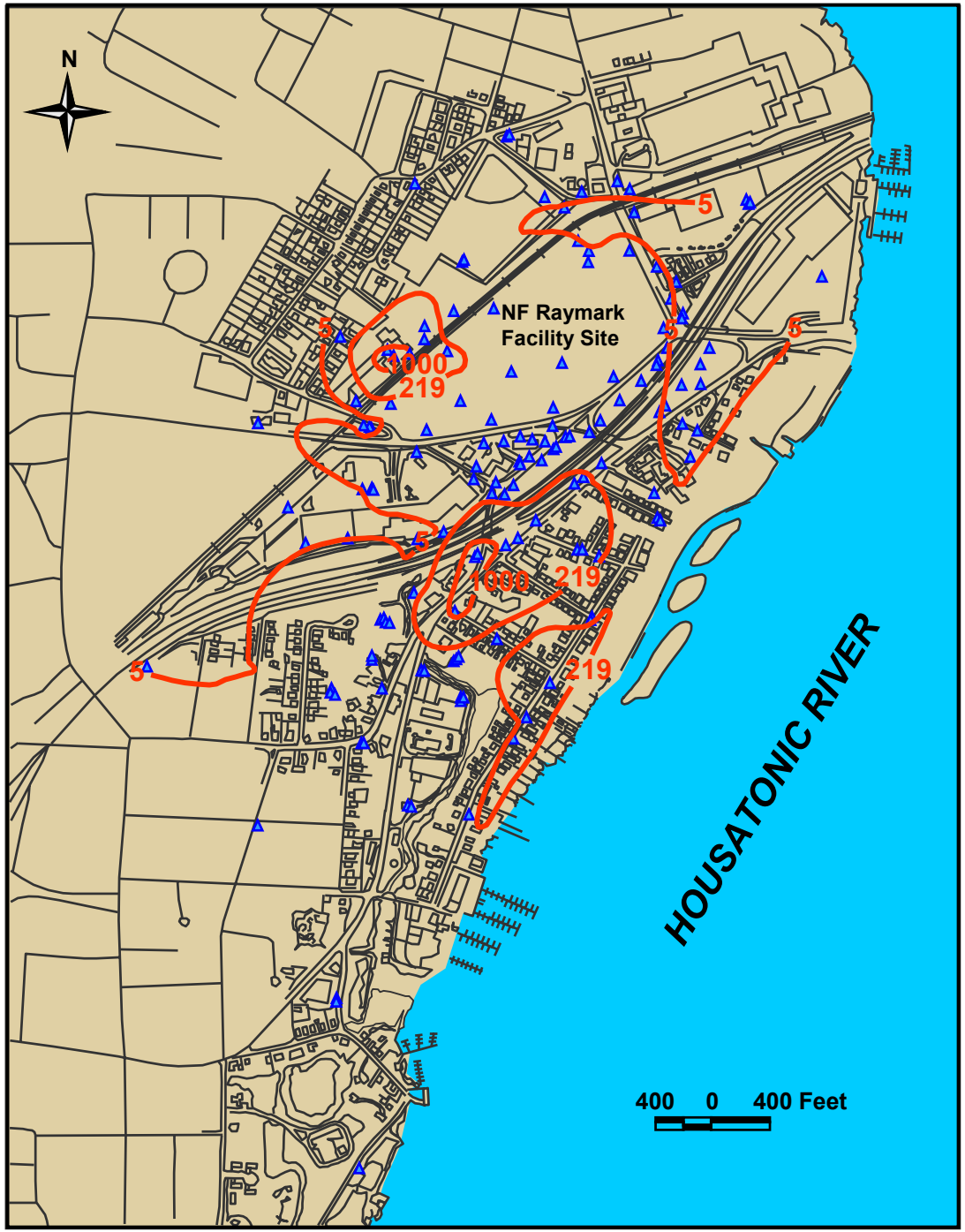
Trichloroethene (TCE) Concentrations (ug/l)



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Typical House at Stratford, Ct

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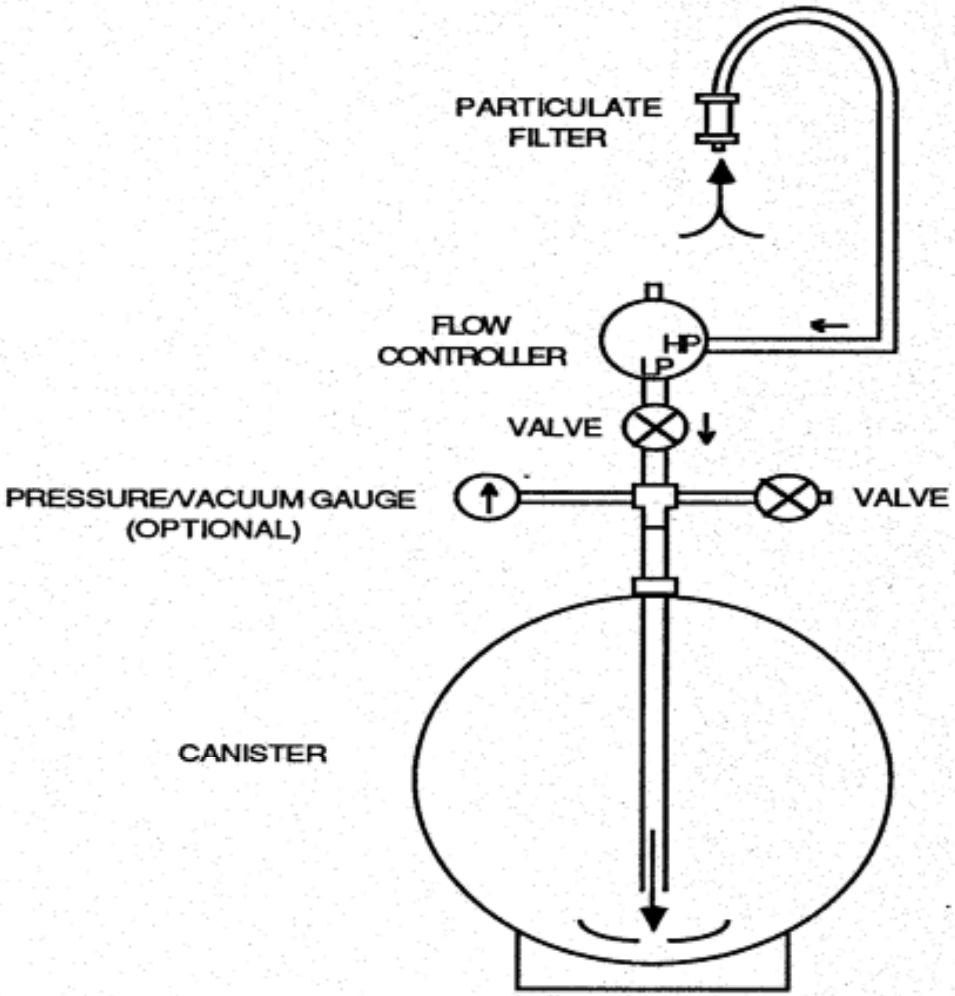
Pre-Sampling Survey

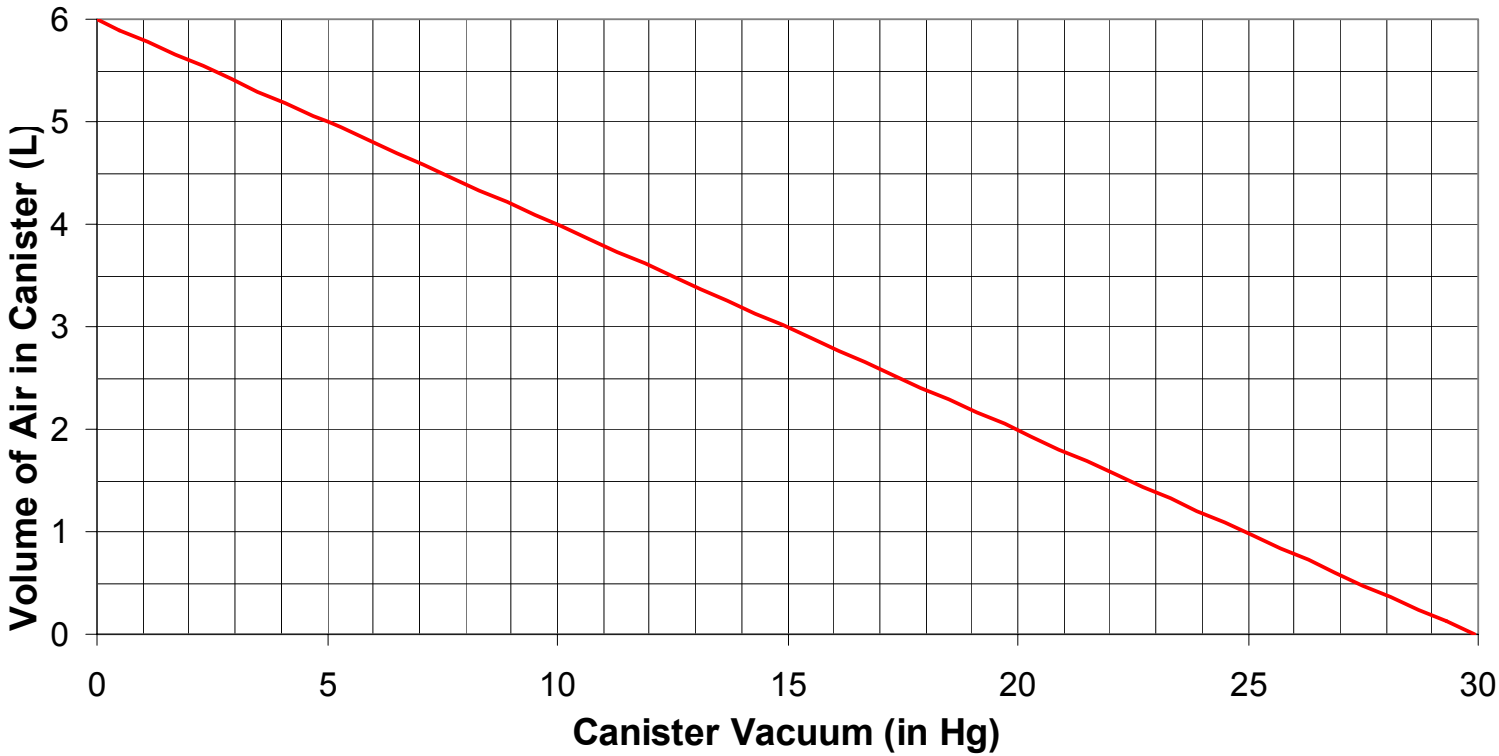
Collecting an Outdoor Sample

Indoor Air Sampling: Collection of a Duplicate Sample

Anatomy of a 6-L Summa Canister Used for Indoor/Outdoor Time Integrated Sampling



Volume of air (STP) as a function of canister vacuum



Locating Utilities: Gas Line Entering Through a Wall

Locating Utilities: Sewer Line Exiting Under the Slab

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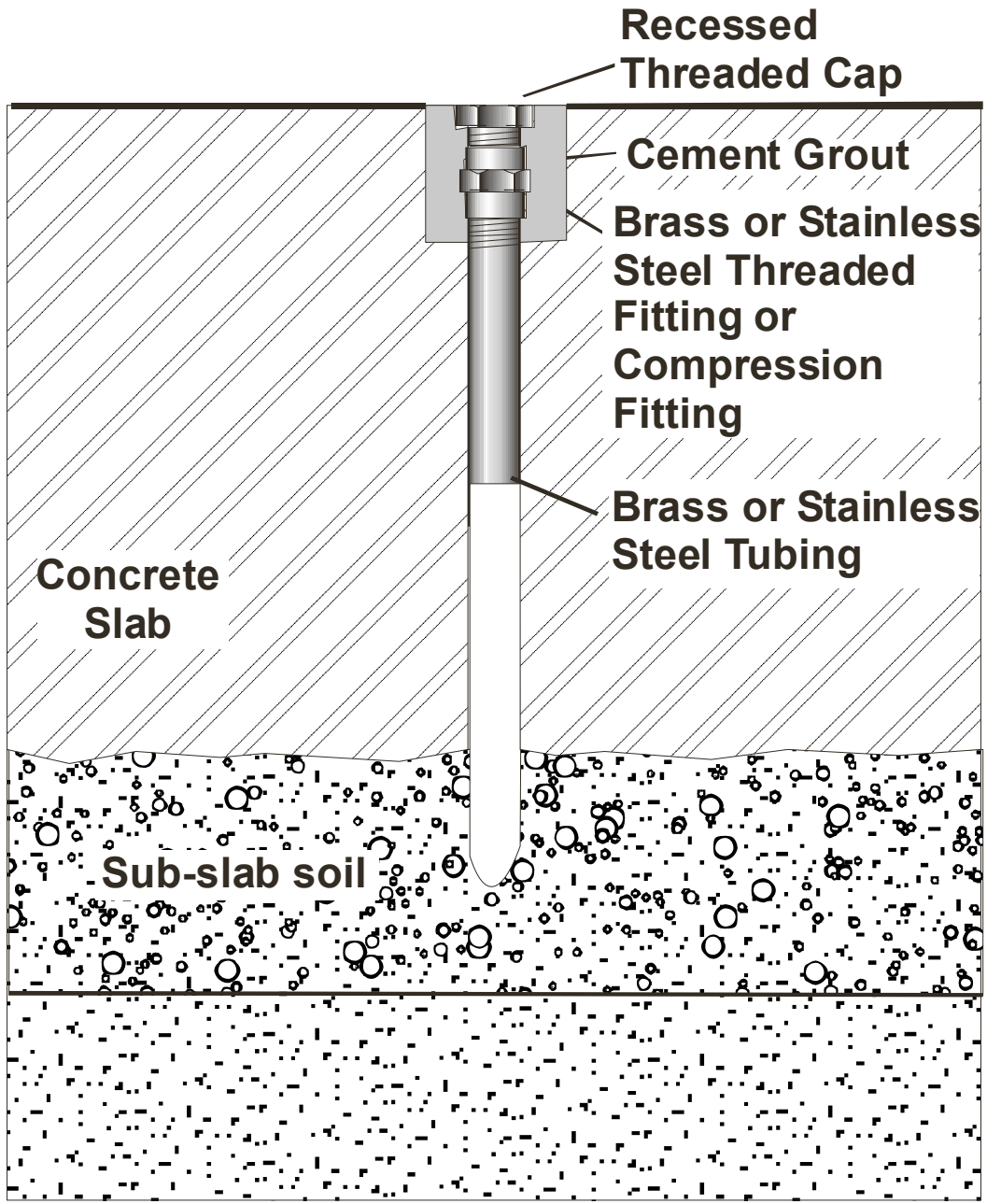
General Schematic for Installation of Sub-Slab Vapor Probes



Drilling a Small Diameter Hole Through A Slab

"Inner" and "Outer" Holes

Probe Used at the Raymark Site

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Purge Before Sampling

Sample Collection into Tedlar Bags

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On-Site GC Analysis of VOCs Using Tedlar Bags

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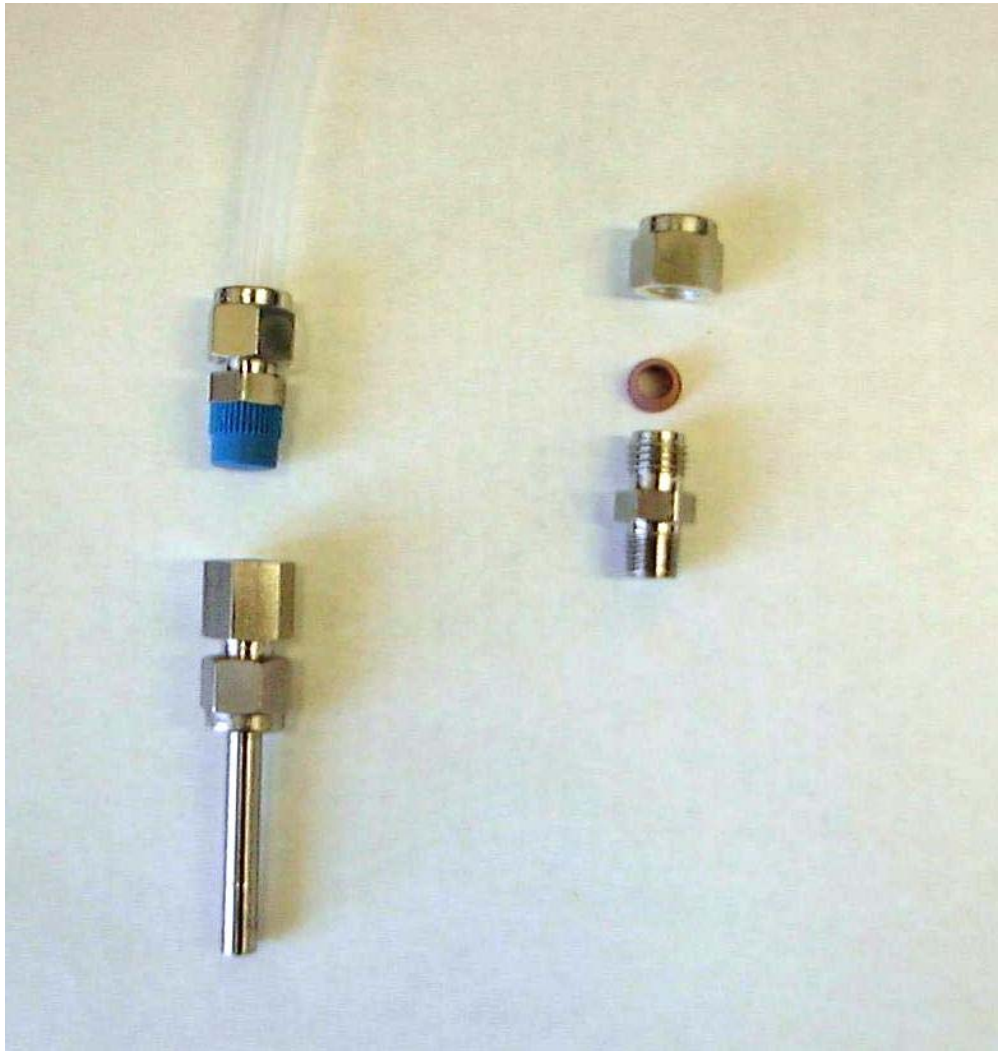
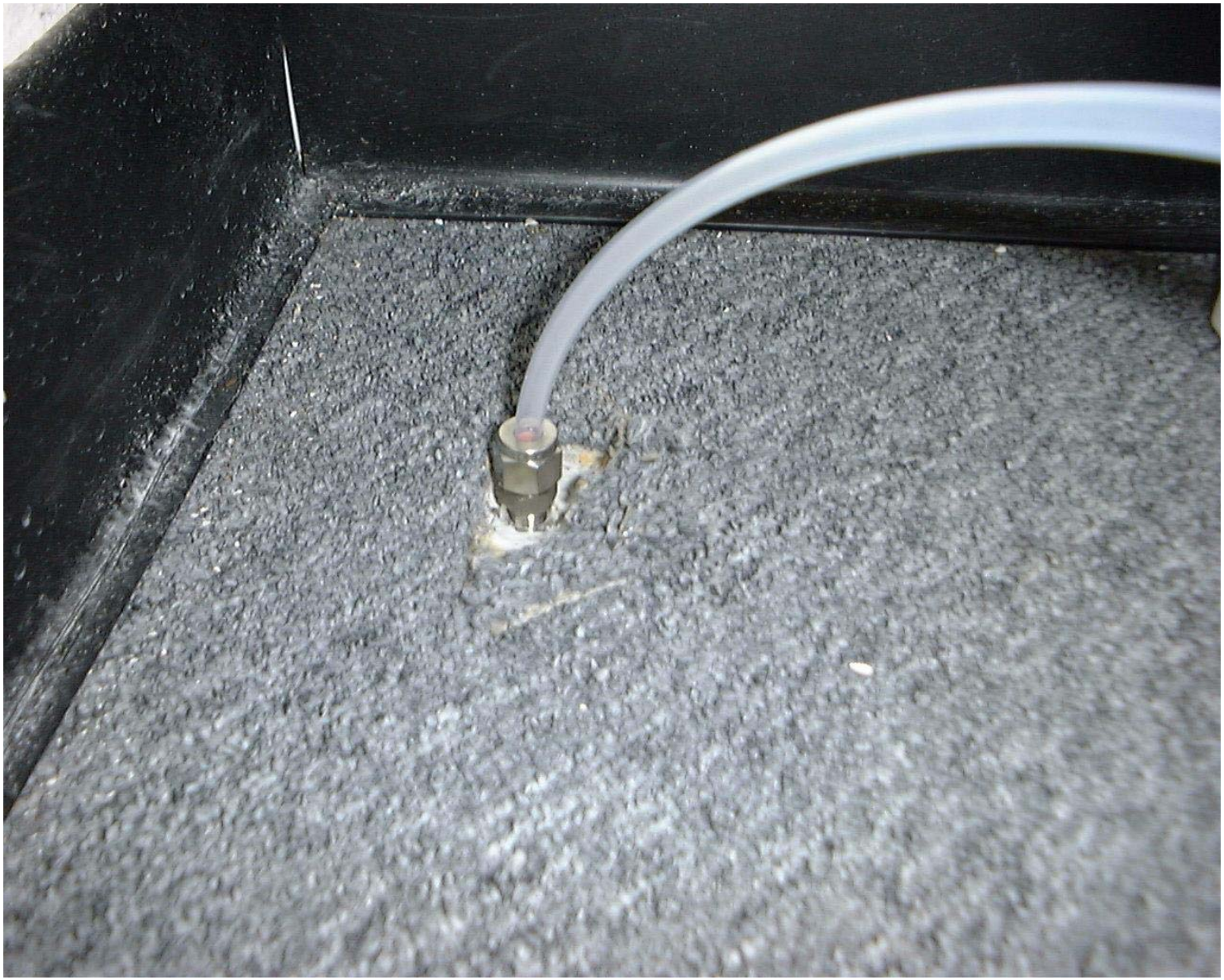
Sampling Sub-Slab Gas with a 6-L Summa Canister

Probe Used at the Ada UST Site (chromatography-grade stainless steel)



Swagelok Fitting to Probe



Sampling for O_2, CO_2 and CH_4 during Purging

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Collection of Duplicates

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Sampling Sub-Slab Gas with a 1-L Summa Canister at the Ada UST Site

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Sources and Significance of Systematic Error in Sub-Slab Sampling

Sources and Significance of Systematic Error: 1. Probe construction materials as a source of VOCs

- Analysis of cement and methanol extract
- Use of equipment blanks
- Use of chromatography-grade stainless steel components

Methanol Extraction of Brass Fittings and Cement Grout for Background VOCs

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Use of a Field Probe Blank at the Raymark Site to Ensure that Probe not a Source of VOCs

COMPOUND	AMBIENT AIR		SAMPLING PROBE FIELD BLANK	
	Canister #6582		Canister #6581	
	(ppb/v)	(ug/m3)	(ppb/v)	(ug/m3)
1,1,1-Trichloroethane	0.58	3.2	ND(0.21)	ND(1.2)
Acetone	4.5 J	11 J	3.1 J	7.3 J
Benzene	0.15 L	0.47 L	0.15 L	0.47 L
Carbon Tetrachloride	0.09 L	0.42 L	0.09 L	0.44 L
Chloroform	0.10 L	0.50 L	ND(0.20)	ND(0.98)
Dichlorodifluoromethane	0.66	3.3	0.59	2.9
Ethylbenzene	0.20 L	0.87 L	ND(0.21)	ND(0.91)
Hexane	1.0	3.7	0.18 L	0.64 L
Methyl-t-Butyl Ketone	0.23	0.81	0.47	1.7
Methylene Chloride	0.44	1.5	0.12 L	0.43 L
Toluene	0.85	3.2	0.42	1.6
Trichlorofluoromethane	0.27	1.5	0.27	1.5
Trichlorotrifluoroethane	0.10 L	0.78 L	0.10 L	0.78 L
m/p-Xylenes	0.65	2.8	ND(0.41)	ND(1.8)
o-Xylene	0.25	1.1	0.08 L	0.34 L

NOTES: ND = Not detected above reporting limits

L = estimated value, below the calibration range

J = Estimated value

Compounds in bold are project target analytes

Sources and Significance of Systematic Error: 2. VOC loss through tedlar bags

- Comparison with TO-15 analysis
- Tedlar bag study at GWERD

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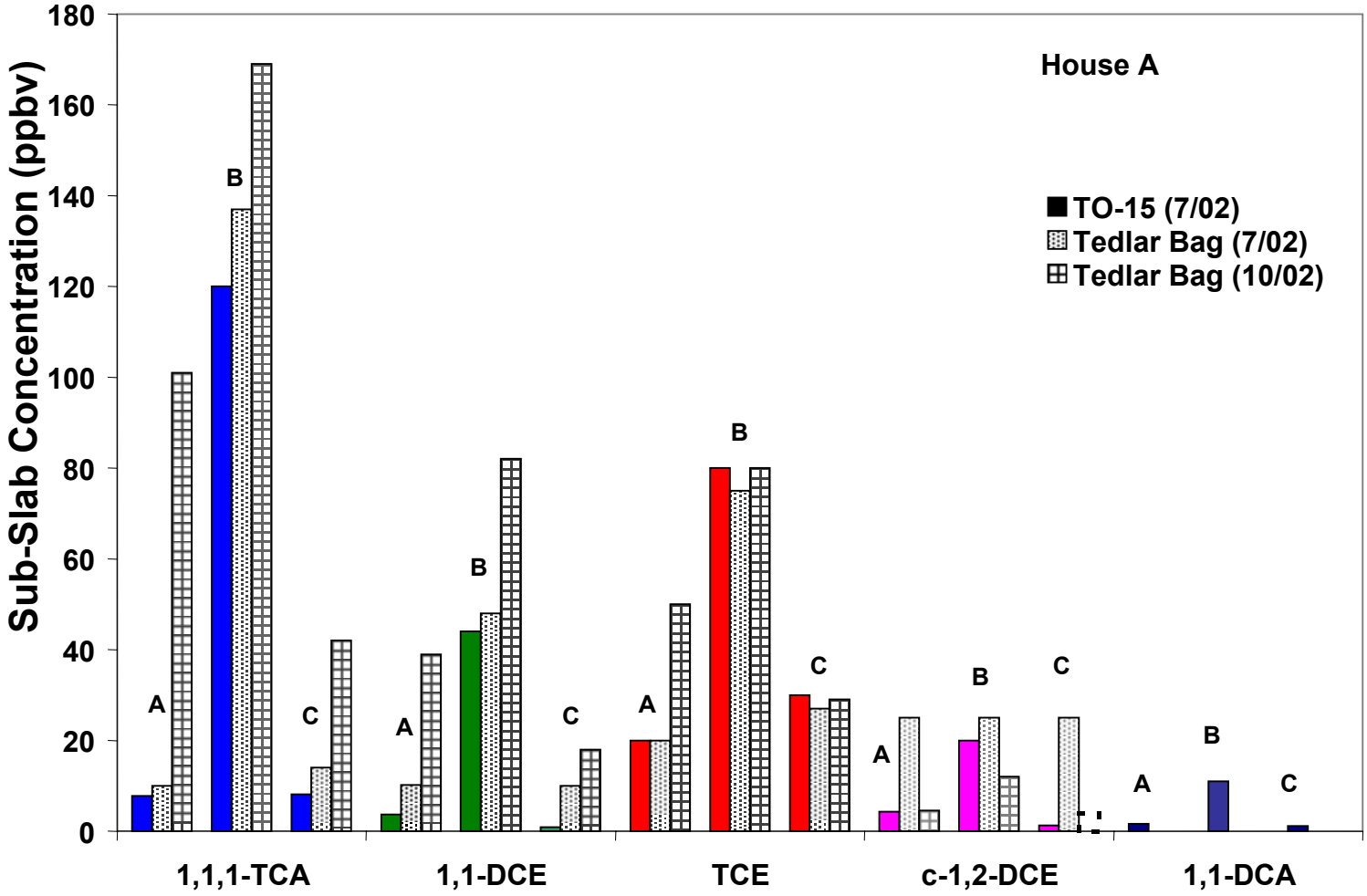
Comparison with TO-15 Analysis



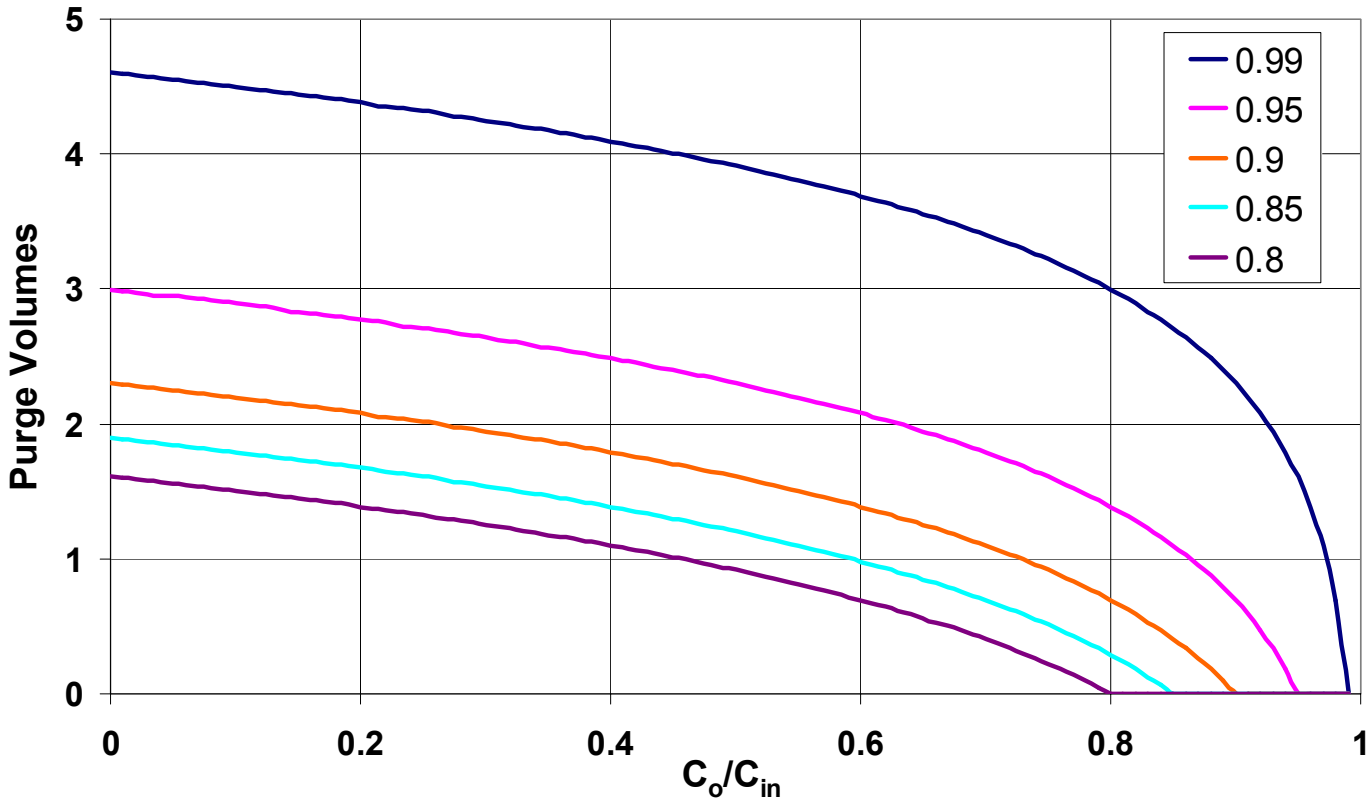
Sources and Significance of Systematic Error: 3. Insufficient or excessive purge volume

- Mathematical analysis (mass balance, 2-D particle tracking, “air-gap” calculation)
- Direct sampling

Calculation of Purge Volume Requirement: Method 1 - Mass Balance

$$\frac{dC}{dt} = \frac{Q}{V}(C_{in} - C) \qquad purge\,volume = \frac{tQ}{V} = \ln\left|\frac{C_{in} - C_0}{C_{in} - C_{out}}\right|$$

$$C(0) = C_0$$



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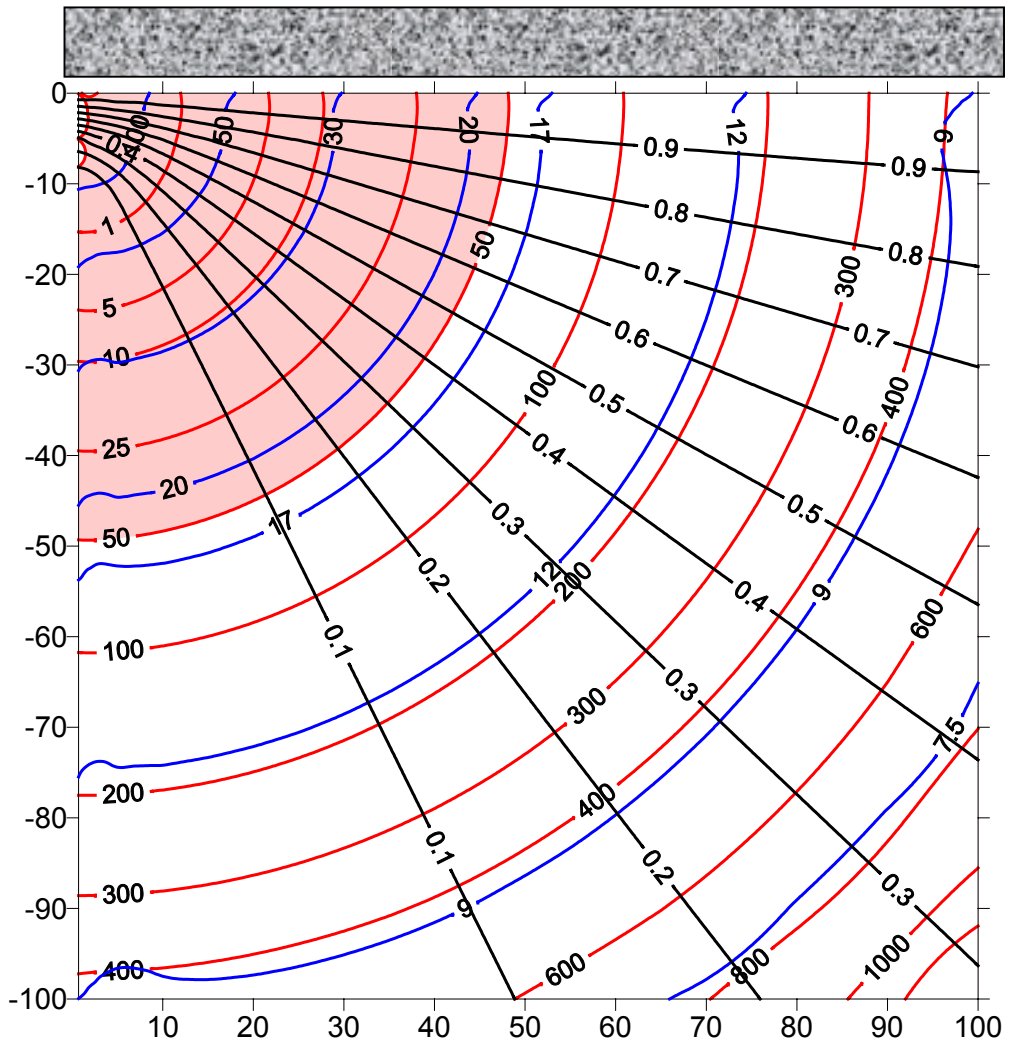
Calculation of Purge Volume: Method 2 – Particle Tracking

Simulated pressure differential (Pa), streamlines, and travel time (min) Below a slab during air sampling at 1 LPM

L_{slab} = 13 cm
$L_{water\text{-}table}$ = 1000 cm
K_{slab} = 1.0×10^{-10} cm^2
$K_{sub\text{-}slab}$ = 5.0×10^{-08} cm^2
K_{soil} = 5.0×10^{-08} cm^2
R_w = 0.7 cm
θ_g = 0.2

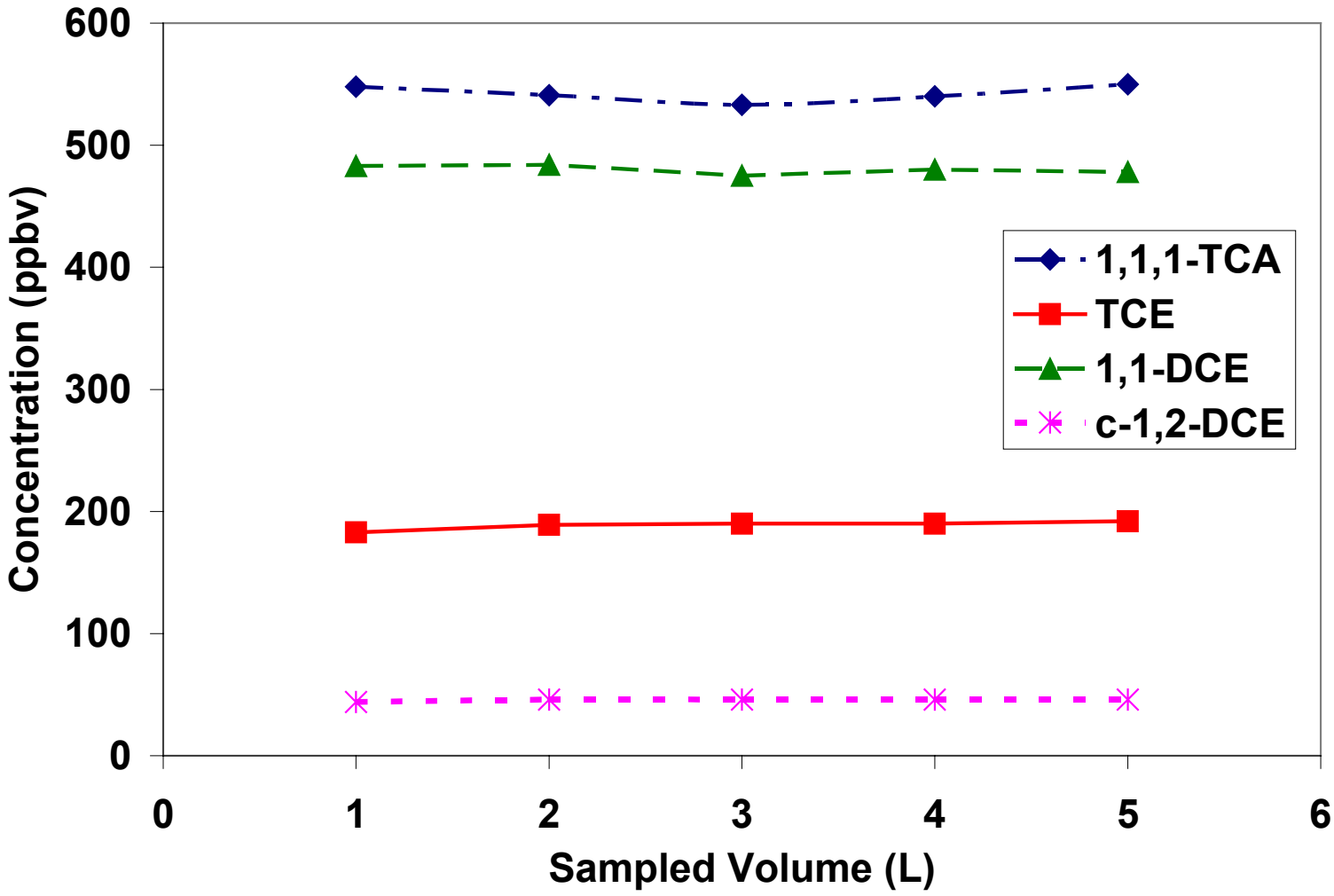


Calculation of Purge Volume: Method 3 – Void Under Slab

V (L)	D (ft)
1	1.5
2	2.1
3	2.5
4	2.9
5	3.3
6	3.6
7	3.9
8	4.2
9	4.4
10	4.6
11	4.9
12	5.1
13	5.3
14	5.5
15	5.7

- Internal volume of sub-slab probe is insignificant (< 5 cm^3)
- Assume thickness of air space underneath slab is ¼”

Concentration as a Function of Sample Sequence at House F



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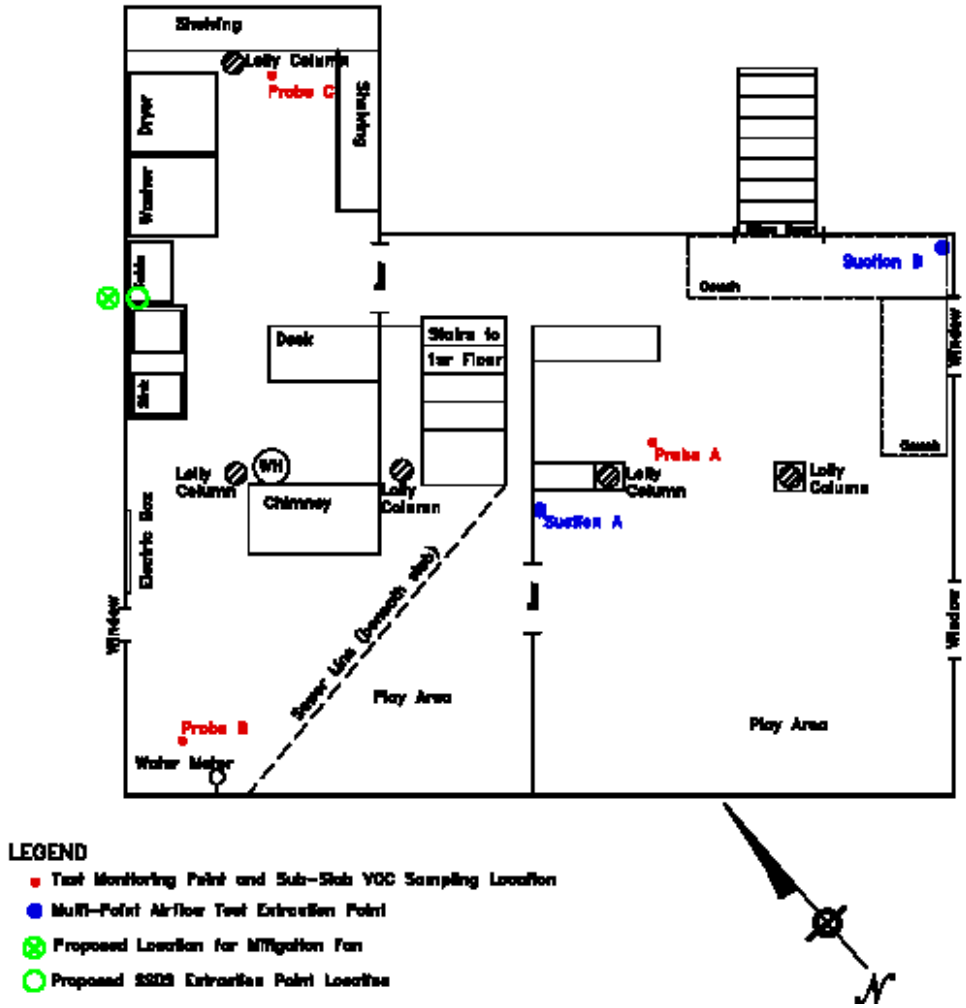
Sources and Significance of Systematic Error: 4. Location of sub-slab samples



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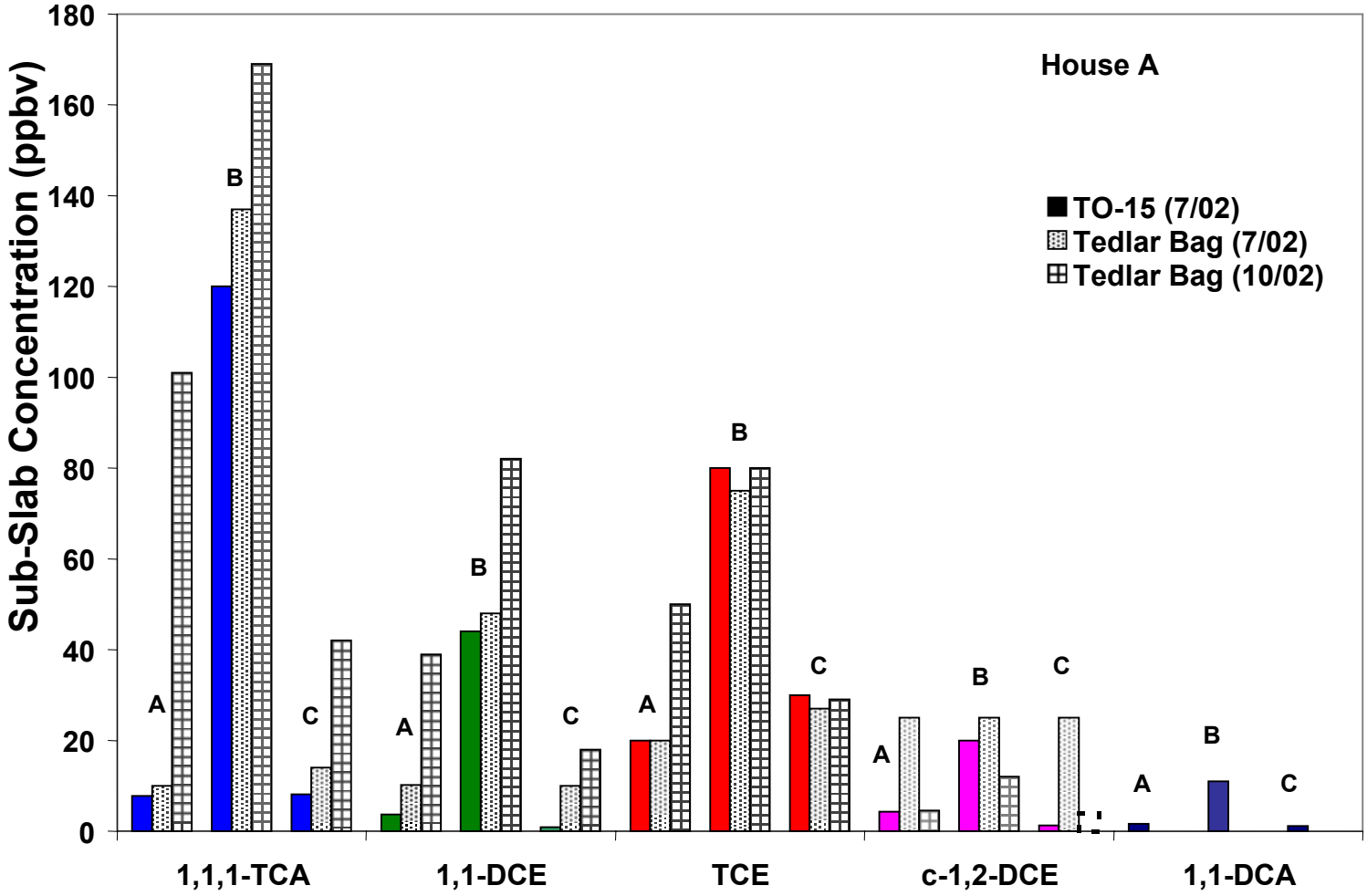
Comparison of Sampling Locations



Major Data Interpretation Issues Associated with Sub-Slab Sampling (ongoing analysis of data)

- Logic (algorithm) used and data requirements to discern sources of VOCs in indoor air
- TO-15 analysis versus on-site GC analysis for subset of compounds
- Minimum number of probes per sample area to calculate indoor air/sub-slab concentration ratios (spatial variability)
- Temporal variability

Preliminary Results and Findings (focus of AEHS meeting in March)

- A protocol has been developed which allows rapid and inexpensive installation of sub-slab vapor probes with minimal disturbance to occupants.
- At least 3 sub-slab vapor probes samples should be installed in a typical home to calculate indoor air/sub-slab concentration ratios and assess associated spatial variability. Commercial buildings with larger area slabs will require more probes.
- Placement of sub-slab probes in the center of a slab does not consistently result in detection of higher vapor concentrations.
- The sub-slab sampling protocol appears to be free of systematic error

Preliminary Findings

- An algorithm or flowchart has been developed to discern the source(s) of VOCs in indoor. The following data (and associated data is necessary)
  - indoor air samples (TO-15 or equivalent)
  - Outdoor air samples (TO-15 or equivalent) in the “vicinity” of indoor air sampling locations
  - Sub-slab air samples (TO-15 or equivalent)
  - A conservative VOC compound in sub-slab air (e.g., 1,1-DCE) or use of radon to calculate indoor-air/sub-slab concentration ratios.
  - VOC analysis in ground-water and/or soil-gas (TO-15 preferred) in the “vicinity” indoor sampling locations may be necessary at some locations)

Use of Algorithm Allow Differentiation of Sources of Indoor Air Contamination into the Following Categories

- Outdoor air as the likely primary source
- Indoor air as the likely primary source
- Sub-slab gas as the likely primary source
- Combination of indoor and outdoor air as the likely primary source
- Outdoor, indoor, or a combination of indoor and outdoor air as the likely primary source
- Indoor air or a combination of indoor air and sub-slab gas as the likely primary source
- Outdoor air or a combination of outdoor air and sub-slab gas as the likely primary source
- Indeterminate

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Questions?